[0023] The transverse magnetization resulting from a small-tip excitation due to a single transmit coil may be analyzed by the Fourier transform of the k-space trajectory traversed and weighted during the excitation:

$$M(\mathbf{x}) = b(\mathbf{x})\int_{\mathbf{k}} W(\mathbf{k})S(\mathbf{k})e^{i2\pi\mathbf{x}\cdot\mathbf{k}}d\mathbf{k} \qquad (1)$$

where $b(\mathbf{x})$ describes the spatial variation of the transmit coil's B_1 field, $W(\mathbf{k})$, a spatial frequency weighting controlled by the time-varying current driving the coil, and $S(\mathbf{k})$, a spatial frequency sampling trajectory controlled by the time-varying gradient field ($W(\mathbf{k})$ and $S(\mathbf{k})$ are described in greater detail in US Patent 4,985,677 to Pauly which relates them to the currents in the RF transmit coil and gradient coils).

In a further case of parallel excitation with a transmit coil array that are independently driven by associated RF amplifiers, linearity leads to:

$$M(\mathbf{x}) = \sum_n b_n(\mathbf{x})\int_{\mathbf{k}} W_n(\mathbf{k})S(\mathbf{k})e^{i2\pi\mathbf{x}\cdot\mathbf{k}}d\mathbf{k} \qquad (2)$$

where n is the coil index. To achieve an example 2D focused excitation with localization along both x and y as specified by $M(\mathbf{x})=f(x)\cdot g(y)$, we consider the use of an echo planar trajectory with Δ_{kx} separation between adjacent lines, multiple transmit coils lined up uniformly along x and $W_n(\mathbf{k})$'s of form $W_n(\mathbf{k})=u_n(k_x)v(k_y)$, Eqn.2 then becomes:

$$f(x) = \sum_n b(x-n\Delta_x)\left(\sum_m u_n(m\Delta_{kx})e^{i2\pi x m\Delta_{kx}}\right) \qquad (3)$$
$$g(y) = \int_{k_y} v(k_y)e^{i2\pi y k_y}dk_y$$

[0024] For simplicity, $b_n(x)$'s are assumed to have negligible y- or z-direction variation in the targeted volume and may be described by $b(x-n\Delta_x)$'s.

[0025] In a body coil transmit case (i.e., single coil with $b(x)$ ˜ 1), it is well understood that an appropriate design for $u(m\Delta_{kx})$ is the Fourier transform of $f(x)$ and that Δ_{kx} must be small enough to prevent aliasing side lobes from locating inside the examined subject, which is detailed in US Patent 4,985,677 to Pauly. With multiple coils transmitting in parallel, it is conceivable that one may accomplish a comparable localization at a reduced excitation k-space sampling density while an increased Δ_{kx} causes aliasing lobes to locate inside the subject, incoherent addition achieved with an appropriate design of the $u_n(m\Delta_{kx})$'s may reduce/annihilate their net amplitudes. Specifically, it is to be noted that $f(x)$ is a spatially-weighted sum of several periodic functions (period$=1/\Delta_{kx}$). The task of eliminating aliasing side lobes parallels the de-aliasing of a Cartesian-trajectory

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where n is the coil index. To achieve an example 2D focused excitation with localization along both x and y as specified by $M(\mathbf{x})=f(x)\cdot g(y)$, we consider the use of an echo planar trajectory with Δ_{kx} separation between adjacent lines, multiple transmit coils lined up uniformly along x and $W_n(\mathbf{k})$'s of form $W_n(\mathbf{k})=u_n(k_x)v(k_y)$, Eqn.2 then becomes:

$$\begin{aligned} f(x) &= \sum_n b(x-n\Delta_x)\left(\sum_m u_n(m\Delta_{kx})e^{j2\pi xm\Delta_{kx}}\right) \\ g(y) &= \int_{k_y} v(k_y)e^{j2\pi yk_y}dk_y \end{aligned} \qquad (3)$$

[0024] For simplicity, $b_n(x)$'s are assumed to have negligible y- or z-direction variation in the targeted volume and may be described by $b(x-n\Delta_x)$'s.

[0025] In a body coil transmit case (i.e., single coil with $b(x)$ ˜ 1), it is well unde that an appropriate design for $u(m\Delta_{kx})$ is the Fourier transform of $f(x)$ a Δ_{kx} must be small enough to prevent aliasing side lobes from locating insid examined subject, which is detailed in US Patent 4,985,677 to Pauly. With mu coils transmitting in parallel, it is conceivable that one may accomplish a comparable localization at a reduced excitation k-space sampling density wh increased Δ_{kx} causes aliasing lobes to locate inside the subject, incoherent

SENSE reconstruction which may be shown to be in effect calculating a spatially-weighted sum of periodic functions (images).

[0026] To design the $u_n(m\Delta_{kx})$'s given the f and the b's, we note that if one computes, based on b, Δ_x and Δ_{kx}, a function β that is the dual frame of b, then $u_n(m\Delta_{kx})$'s evaluated as in the following will satisfy Eqn.3:

$$u_n(m\Delta_{kx}) = \int_x f(x)\beta^*(x - n\Delta_x)e^{-i2\pi m\Delta_{kx}x}dx \qquad (4)$$

[0027] To avoid alising lobes while creating desired main lobe Eqn.4 suggests the k-space weighting contributed by the n^{th} coil be the Fourier transform of a spatially weighted version of f. A robust numerical algorithm for computing β has been developed, for the situation where $\Delta_{kx} < 1/\Delta_x$. The robustness of aliasing lobe elimination against perturbation is fundamentally determined by b, Δ_x and Δ_{kx}, in much the same way as is the robustness or SNR-characteristic of a SENSE acquisition with a corresponding setup.

[0028] Referring to Figure 2, there is shown an embodiment of a transmit coil 200 in which ten coils 210 are aligned in a linear fashion along the x-axis. While a conventional 2D selective excitation pulse may produce localization along two spatial dimensions and thus expedite subsequent spatial encoding, the excitation often involves time-consuming 2D k-space traversing. In this embodiment, multiple transmit coils 210 exciting in parallel speedup 2D excitation as excitation k-space sampling density is lowered yet aliasing side lobes in examined subjects are minimized. This is achieved by exploiting the spatial and spatial-frequency weighting associated with the transmit coils in a way described above.

[0029] An example small-tip-angle excitation using these ten coils transmitting in parallel was simulated. The coils in this example were 19.8cm x 6.4cm rectangular loop coils and were lined up along x with a uniform center-to-center spacing of 4cm (Fig.2). Driven by the gradient field, an echo planar trajectory sampled the excitation $k_x - k_y$ plane with k_x being the slow traverse direction.

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SENSE reconstruction which may be shown to be in effect calculating weighted sum of periodic functions (images).

[0026] To design the $u_n(m\Delta_{kx})$'s given the f and the b's, we note th computes, based on b, Δ_x and Δ_{kx}, a function β that is the dual fr $u_n(m\Delta_{kx})$'s evaluated as in the following will satisfy Eqn.3:

-j2πxmΔkx

$$u_n(m\Delta_{kx}) = \int_x f(x)\beta^*(x - n\Delta_x)e^{-j2\pi x m\Delta_{kx}}dx \qquad (4)$$

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[0029] An example small-tip-angle excitation using these ten coils transr parallel was simulated. The coils in this example were 10.8cm x 6.4cm